Journal of Advanced Research (2011) 2, 195–198

Cairo University

Journal of Advanced Research

EDITORIAL

Special Issue on "Mobile Ad-Hoc Wireless Networks"

Mobile Ad Hoc wireless Networks (MANETs) is defined as a multi-hop infrastructureless wireless network which is self-organized and connects two or more stations spontaneously in the absence of central point or any access point. It allows peer-to-peer connections between devices that are operating in ad-hoc mode and are within the wireless range. They can form standalone groups of wireless nodes and can be connected to a cellular or fixed network. Nodes in a mobile ad-hoc network are free to move and organize themselves in an arbitrary fashion. Each user is free to roam about while communicating with others. Ad-hoc networks are suited for use in situations where an infrastructure is unavailable or when the costs to deploy one are very high.

Mobile ad-hoc networking is a multi-layer architecture that normally involves the physical, medium access layer (MAC), network layer and transport layers. Nodes in ad-hoc networks perform self-organization. Their tasks include neighbor discovery and topology organization and reorganization. Every node looks for activities from its neighbor and exchange topology information periodically. Additionally, ad-hoc networks have self-configuring and self-healing capabilities. Ad-hoc networks are also very scalable. The hybrid architectures in ad-hoc networks can increase scalability by combining multi-hop relaying and base stations.

Ad-hoc wireless networks can easily address the shortcomings of presently available wireless networks. They can also improve the efficiency of wireless networks. The application of this technology is far-reaching as it can achieve numerous functionalities which have never been possible before. Hence, development of wireless Ad-hoc networks can immensely change the way we visualize, implement, and use the wireless technology today.

Ad-Hoc networks have many applications. For home applications, smart sensor nodes and actuators can be buried in appliances to allow end users to manage home devices locally and remotely. Concerning environmental applications, ad-hoc networks can be used to track the movements of animals, chemical/biological detection, precision agriculture, etc. They can also be used in healthcare industry by getting early retrieval and transmission of patient data (record, status, diagnosis) from/to the hospital. The patients' health can be monitored remotely. In e-commerce, wireless ad-hoc networks can be used for electronic payments from anywhere. Ad-hoc networks have many applications in the military environment. They are widely used for communications in the battlefield and for tracking all military vehicles and equipment without the need of a centralized controller. They can be used for battlefield communication as well. Ad-hoc networks can also be utilized in sensor networks. A mobile ad-hoc network can also be used to provide crisis management services, such as in disaster recovery, where the entire communication infrastructure is destroyed and restoring communication quickly is crucial. By using a mobile ad-hoc network, an infrastructure could be set up in hours instead of weeks, as is required in the case of wired line communication.

One of the key applications of wireless ad-hoc networks is in the field of vehicular services. They can perform transmission of news, road condition, weather, music, etc. The local ad-hoc network with nearby vehicles can provide information such as road/accident guidance. In the field of education, we would be able to setup virtual classrooms or conference rooms as well as setting up ad-hoc communication during conferences, meetings, or lectures. Additionally, wireless ad-hoc networks will enable outdoor internet access at any time and at any place. This concept can also be extended to satellite communications where the individual satellites can setup an ad-hoc network amongst themselves. This will enable them to set up a network that could potentially reach other planets.

This special issue on mobile ad-hoc wireless networks provides recent research work covering various topics in this field. The issue contains seven research papers. The first paper, *Power Control Algorithms for Mobile Ad-Hoc Wireless Networks by Nuraj Pradhan and Tarek Saadawi*, discusses the power control algorithms in mobile ad-hoc networks. In Ad-hoc networks, the main goal of power control algorithm is to achieve connectivity while preserving nodes power. Due to the absence of centralized controller node to administer the power management, managing network topology and energy

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efficiency is a big challenge especially in large networks that comprises many nodes. Power control techniques can substantially improve the wireless ad-hoc networks' capacity and lifetime. Currently the algorithms used in ad-hoc networks are deterministic or probabilistic techniques.

This paper presents a brief survey of the various approaches to deal with power control management in mobile ad-hoc wireless networks. They are classified into the following five approaches: (a) Node-Degree Constrained Approach - provides a mechanism to provide a theoretical lower bound on node degree to build network topology; (b) Location Information Based Approach - attempts to benefit from geographical location of nodes using directional antenna; (c) Graph Theory Approach - builds a network graph that minimizes some kind of cost function; (d) Game Theory Approach - models the interaction among the nodes in the network using game theory to maximize their own objectives; (e) Multi-Parameter Optimization Approach –a dynamic multi-parameter optimization of different parameters such as connectivity, interference and energy consumption of the network. The focus of this paper is on distributed power management (DISPOW), which manages nodes' power in a dynamic wireless ad-hoc mobile network to preserve network connectivity, conserve energy consumption, and reduce interference cooperatively. A detailed mathematical description of DISPOW is presented. DISPOW algorithm builds a unique stable network topology tailored to its surrounding node density and propagation environment over random topologies in a dynamic mobile wireless channel. DISPOW possesses a receiver-based interference model which lowers the inter-node interference. It also has the ability to convert asymmetric links into symmetric links whenever required. By operating DISPOW in a distributed manner, it is scalable and can be readily applied to large heterogeneous networks.

The algorithm presented is then tested with a test simulation. The simulation results show that using DISPOW leads to less power consumption. In fact, the test showed a 32 percent reduction in the average total interference in an equal energy-consuming network. In addition, it was shown that DISPOW adapts better to the changes in the network resulting from node mobility and dynamic wireless channel variations.

The second paper, Secured Operating Regions of Slotted ALOHA in the Presence of Interfering Signals from Other Networks and DoS Attacking Signals by Jahangir H. Sarker and Hussein T. Mouftah, discusses the area of security attacks. Radio interference and jamming attacks can effectively cause a denial of service (DoS) in either the transmission or reception capabilities of wireless networks. Much research is being done to analyze the wireless multiple access schemes in the presence of jamming or attacking signals. This paper addresses critical issues that can be faced by Slotted ALOHA based networks. In the case of wireless mobile ad-hoc networks, the Slotted ALOHA is a preferable choice due to its adequate working capability with distributed wireless nodes that exhibit busy traffic. This paper investigates the combined effects of the interfering signals from other networks and the DOS attacking signals. A slotted ALOHA system can be disrupted by interfering signals emerging from surrounding networks as well as by random packet destruction Denial of Service (DOS) attacks. This paper aims to address these issues by presenting four different techniques for making secured operating regions enhancements of Slotted ALOHA protocol. All four techniques can be easily implemented and can prevent a possible shutdown of the Slotted ALOHA based network.

The paper first presents mathematical results to obtain the throughput of Slotted ALOHA in the presence of the interfering signals from other networks and the random packet destruction DOS attack. From the equation derived, it was shown that the new packet generation rate, number of channels, new packet rejection probability, capture ratios, and number of retransmission trials all play an important role in the equation derived. It is shown that the effect of interfering signals and DOS attacks can be reduced by the following: Firstly, by increasing the number of channels to an optimal level using the mathematical results derived. Using multiple channels reduces three types of packet collisions. The first type of collision is between two or more message packets. The second type is between a message packet and one or more interfering packets from other networks. The third type is between a message packet and one or more other attacking noise packets. Secondly, one may use effective message capturing techniques. A lower message capture ratio can increase the throughput and maximum throughput significantly. However, it is important to note that a lower interfering capture ratio can increase the throughput and maximum throughput only if the rate of interfering signals from other network's packets rate is high. The exact same conclusion is applied for a lower attacking capture ratio. Thirdly, one could use the retransmission cut-off technique, which limits the number of retransmission trials. Lastly, we can adjust the new packet rejection probability. The optimum values of these parameters are calculated on the basis of mathematical results derived in this paper.

The paper concludes that by using the mathematical results and techniques mentioned in this paper, we can mitigate the effects of interfering signals from other networks and DOS Attacking Signals. Current security measure techniques utilize encryption, authentication and authorization that are not sufficient to provide foolproof security for wireless networks.

The third paper, *IEEE 802.11e (EDCA) Analysis in the Presence of Hidden Stations by Xijie Liu and Tarek Saadawi*, provides a performance analysis of IEEE 802.11e Enhanced Distributed Channel Access (EDCA) in the presence of hidden stations and non-saturated conditions. IEEE 802.11e is basically an improvement to the IEEE 802.11 standard. It is a complex access protocol that addresses Quality of Service enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer. The development of this standard is very important for delay-sensitive applications such as Voice over Wireless LANs and the streaming of multimedia. Various research works have been presented in the past to analyze the performance of the protocol in various environments and conditions. This paper analyzes the performance of IEEE 802.11e in the presence of both hidden stations as well as in non-saturated conditions (which includes the saturation mode as well).

The paper describes the analytical model for IEE 802.11e (EDCA) with non-saturated conditions as well as hidden stations. A non-saturated Markov chain is developed for IEEE 802.11e (EDCA) as part of making the analytical model for non-saturation. Hidden station effect is then added to the model. Numerical analyses are then performed for the proposed model. The analytical model presented helps to determine the maximum achievable saturation throughput. The throughput results with and without the hidden station effect for both basic access and RTS/CTS (Request to Send / Clear to Send) access are presented. It was observed that the throughput varies depending on the access categories. When comparing the throughput results from the tests with and that of the tests without the hidden station effect, it was observed that the throughput degrades for the RTS/CTS case when compared with the Basic Access case. Hence, this paper extends earlier works by other authors dealing with IEEE 802.11e. The model presented applied the Markov chain model for IEEE 802.11e under non-saturation conditions and effects of the hidden stations. The results presented in the paper aim to calculate the throughput versus the number of stations for different access categories.

The fourth paper, *Performance Evaluation of Neighbor Discovery in Proactive Routing Protocols, by Andres Medina and Stephan Bohacek*, provides a comprehensive study about the performance evaluation of neighbor discovery mechanisms in mobile ad-hoc networks. This paper develops a detailed performance model of neighbor discovery and shows that the degree estimation agreed within a 5% error margin, with simulations. This paper discusses Type I errors and Type II errors. A Type I error occurs when a node believes that it has a neighbor when in fact it is not able to communicate with it, while a Type II error occurs when a node is unaware that it is able to communicate with a node. The performance model developed in this paper evaluates the average number of neighbors a node believes it has, probability of type I and type II errors, the impact of neighbor discovery on connectivity, and link flap rate.

First, the paper discusses neighbor discovery performance model. The performance model is made up of three parts: the radio model, the neighbor detection model, and the mobility model. The model proposed calculates the probability of error in a packet transmission over a link as a function of the length of the link and the level of channel utilization in the network. Two types of neighbor detection schemes are discussed. The first method is Event Driven Neighbor Detection (ED) which is a generalization of the neighbor detection mechanism (NDM). The second method is Exponential Moving Average Neighbor Detection mechanism (EMA) which is thought to be a method to enhance the robustness of link sensing. For each NDM, a Markov Chain Model is used to model the state of a link. A relative trajectory model is presented and is validated for two different mobility models, namely nodes moving on a torus in fixed, but random, directions and random way point mobility. The results of the simulation are very much in line with the analytical results obtained. In addition, as nodes move closer together, the probability that Hello messages are successfully received increases, thus increasing the probability that the link is classified as symmetric. Also the probability that a link is classified asymmetric not only depends on the current link loss probability, but also on the past loss probability. More specifically, the probability that a link is symmetric depends on the trajectory of the link loss probability, which in turn depends on the trajectory of the distance between the nodes. The paper then presents a mathematical equation to determine the average number of symmetric links. The analysis of the equations shows that speed has significance on the number of symmetric links and the number of symmetric links decreases with congestion. The proposed model achieves the smallest neighbor estimation errors. The paper also addresses the issues of link flap by considering the rate at which links go from non-symmetric to symmetric.

Hence, the authors conclude that for the performance evaluation of MANETs, consideration of neighbor discovery process is very important. This paper gives very good insight by studying a wide range of behaviors including the average number of symmetric links, type I and type II errors in the neighbor detection process, and the impact of neighbor discovery on connectivity and link flap.

The fifth paper, ComboCoding: Combined Intra/Inter-Flow Network Coding for TCP over Disruptive MANETs by Chien-Chia Chen, Clifford Chen, Soon Oh, Joon-Song Park, Mario Gerla, and M. Yehia Sanadidi focuses on the efficient use of TCP in the lossy wireless network. The paper proposes Combo coding scheme which combines inter-flow and intra-flow coding to provide an efficient use of TCP transmission in disorderly wireless networks. Previously proposed schemes address either the ACK interference problem or the high data loss problem but not both. This paper introduces a hybrid network-coding scheme that is transparent to TCP. It addresses both TCP interference and random loss issues which are encountered during the transmission. Combo coding combines TCP DATA and ACK flows together within one hop and relies on ACK-based redundancy control, which has high overheads in disruptive networks. As TCP Data and TCP ACK always travel in opposite direction, it causes interference and introduces loss in multi-hop scenarios, which decreases throughput. Additionally, it has no control overhead since coding redundancy is based on loss rate estimates.

Combo Coding consists of two different types of network coding; inter-flow coding and intra-flow coding. It combines the concepts of Piggy Code and Pipeline coding. This paper refers to inter-flow coding as a modified version of Piggy Code, and intra-flow coding as Pipeline Coding. The use of Pipeline Coding reduces the overall coding delay and is used with adaptive redundancy to reduce high packet loss over non-reliable links. It uses the concept of packet generations, encoding and decoding progressively. On the other hand, Piggy Code is a network-coding scheme designed to enhance TCP performance over IEEE 802.11 multi-hop wireless networks. Its main goal is opportunistically XORing the TCP Data and TCP ACK at intermediate node. This paper highlights four key concepts and features of Combo coding which are: (1) combining inter- and intra-flows coding to address both high loss rate and self-induced interference. (2) Using a novel loss adaptation algorithm that effectively handles transient, unstable link conditions. (3) It is implemented in the network layer and is transparent to TCP and other upper layer protocols thus, making it forward compatible with any future improvement of upper layer protocols. (4) It does not rely on any new or modified MAC layer protocols.

The paper then presents a detailed code flow chart, Loss Adaptation Algorithm and channel access scheme to implement the combo coding. The proposed concepts are then tested by running a simulation. The results show that by using the 3-hops topology, Combo Coding successfully achieves 2 Mbps throughput with 30% per link packet loss rate. As compared to the original Pipeline Coding, Combo Coding reduces transmission overhead by 30% under perfect link conditions and by 10% overhead in most other cases. Hence, it is concluded that by using Combo coding in TCP over disruptive mobile ad-hoc networks, we can achieve better communication results.

The sixth paper, *Self Organization of Nodes in Mobile Ad-Hoc Networks Using Evolutionary Games and Genetic*

Algorithms by Janusz Kusyk, Cem S. Sahin, M. Umit Uyar, Elkin Urrea, and Stephen Gundry, focuses on the critical issues in mobile ad-hoc networks (MANETs) of the optimum organization of the nodes in a geographical area that gives the best and maximum area coverage. This paper proposes a scheme in which MANET nodes place themselves uniformly over a dynamically changing environment in the absence of a centralized controller using a distributed and scalable evolutionary game scheme. The main performance concerns of mobile ad-hoc networks (MANETs) are topology control, spectrum sharing and power consumption, all of which are intensified by the lack of a centralized authority and a dynamic topology. This paper aims to combine forced-based genetic algorithm (FGA), Game theory (GT), and Evolutionary game theory (EGT) to introduce a new approach for handling topology control. The topology control in MANETs can be analyzed from two different perspectives. In one approach, the goal is to manage the configuration of a communication network by establishing links among nodes already positioned in a terrain. In the second approach, the relative and absolute locations of the mobile nodes define the network topology.

In MANETs, for self organizing nodes, finding the best new location for a node that satisfies certain requirements is very difficult. Traditional search algorithms for such problems use sampling or heuristically techniques that are not sufficient. This paper introduces a scheme called node spreading evolutionary game (NSEG), which runs at each individual mobile node. Each individual node in the proposed model asynchronously runs NSEG to make an autonomous decision about its next location. NSEG provides a good solution for the node spreading class of applications used by both military and commercial applications. In the proposed NSEG, every node computes its next preferable location independently without requiring global network information. Every node independently makes movement decisions based on localized data. Forced-based genetic algorithm (FGA) determines the movement probabilities of possible next locations. NSEG is a two-step process that consists of first evaluating the player's current location and spatial game setup. After a player moves to a new location, the node computes the integrity of its current location. Then, it runs FGA to determine a set of possible next locations into which it can move. In spatial game setup, a node decides to move to a new location by constructing its payoff matrix with an entry for each possible strategy profile that can arise among members. The goal of each node is to distribute itself over an unknown geographical terrain in order to obtain a high coverage of the area by the nodes and to achieve a uniform node distribution while keeping the network connected. Each node is aware of its own location and can determine the relative locations of its neighbors. Additionally, every node assesses the fairness of its own location as well.

The proposed model was simulated using a test written in the JAVA programming language. After running NSEG it was observed that even in the early stages of the experiment, the nodes were able to disperse far from their original locations and were able to provide significant improvement of the area coverage while keeping network connected. Hence NSEG, combined with FGA and game theory, can find better future locations for self-spreading autonomous nodes over an unknown geographical territory. The simulation results demonstrate that NSEG performs well with respect to network area coverage, uniform distribution of mobile nodes, and convergence speed.

The seventh paper, *Efficient Content Distribution for Peer-to-Peer Overlays on Mobile Ad-Hoc Networks by Afzal Mawji and Hossam Hassanein*, presents an efficient content distribution scheme. It utilizes network coding and multipoint-to-multipoint communication to provide an efficient means of transferring files between peers in the network. This technique can achieve reduced download times and energy consumption. Peers request file blocks from multiple server nodes and server nodes multicast blocks to multiple receivers, providing efficient multipoint-to-multipoint communication. The peers who are "Client peers" are able to find server peers and download coded blocks, which enables them to retrieve content in less time than downloading un-coded blocks. Server peers transmit data blocks via multicast to enable multiple client peers to download simultaneously.

In a P2P file sharing system, most of the network traffic will consist of the files being transferred through the network. There is no centralized authority and no infrastructure in a P2P–MANET. The proposed scheme uses linear network coding to eliminate the rarest–block problem and multicasting to reduce the number of transmissions where possible. Network coding is a form of information spreading in which nodes use XOR operations to encode several packets together instead of forwarding data packets. Network coding allows nodes to obtain any blocks they could find from servers without worrying about locating specific blocks. Using network coding reduces the likelihood of sending/receiving duplicate data to/from clients and server. One major benefit of network coding is that encoded packets can be further encoded and can save bandwidth. In addition, the use of multicasting enables the server peer to multicast its encoded blocks to several client peers. Clients request a certain number of blocks from multiple servers depending on the cost of acquiring them and how many blocks the servers have, resulting in multipoint-to-multipoint communication. After getting the list of servers, block counts, and hop distances, the client uses a greedy algorithm to determine from whom to download, and how many blocks to request from each server. Furthermore, multicasting blocks allow servers to efficiently deliver data to multiple receivers and reduce transmissions at the server node.

The concepts presented in the paper are then verified by running a test simulation. The performance of the presented scheme was compared to downloading the entire file from a single seed, downloading blocks from multiple servers, and network coding without multicasting. It was shown that the proposed scheme consumed less energy, provided speedier downloads, and had a greater success rate than the competing algorithms. Additionally it was a much fairer scheme as it allowed more peers to participate in the process for uploading the blocks.

Tarek Nazir Saadawi
City University of New York, USA
E-mail: saadawi@ccny.cuny.edu

Hussein Mouftah
University of Ottawa, USA
E-mail: Mouftah@site.uottawa.ca